

BALLAST WITH LOAD-ADAPTABLE FAULT DETECTION CIRCUIT

Field of the Invention

5 The present invention relates to the general subject of circuits for powering discharge lamps. More particularly, the present invention relates to a ballast with a fault detection circuit that adapts to the lamp load.

Background of the Invention

10 Many electronic ballasts for powering gas discharge lamps include a driven half-bridge inverter and a series resonant output circuit. Such ballasts generally include some form of protection circuitry for preventing damage to the inverter and other portions of the ballast in the event of a lamp fault condition. Common lamp fault conditions include lamp removal or lamp failure.

15 A popular protection approach is to place a current-sensing resistor in series with the lower inverter transistor, monitor the voltage across the current-sensing resistor, and shut down the inverter if the voltage across the current-sensing resistor exceeds a predetermined threshold value. While this approach is adequate for protecting against certain fault conditions, such as lamp removal or lamp failure, it does not adequately protect against less well-defined fault
20 conditions, such as the arcing that occurs when a slight air gap is introduced between the pins of a lamp and the sockets of the lighting fixture. Under such an emergent arcing situation, the voltage that develops across the current-sensing resistor will not necessarily be high enough to exceed the predetermined threshold value, in which case the inverter will continue to operate and the
25 potentially dangerous arcing condition will be allowed to continue unabated.

Simply lowering the resistance of the current-sensing resistor (and, thus, the predetermined threshold value) is not a successful remedy to this problem, because that might result in the inverter being improperly shut down even in the absence of a legitimate fault condition. This is especially true for ballasts that
30 must be capable of powering several different types of lamps (e.g., F17T8, F25T8, and F32T8 lamps), in which case the current that flows through the current-sensing resistor during normal operation (i.e., with no fault condition

present) may vary over a considerable range. Thus, in order to avoid false detection of a fault, the predetermined threshold value must be set such that the current through the current-sensing resistor must be much higher than the normal operating value before a fault is detected. Of course, when a mild arcing condition occurs, the current that flows through the current-sensing resistor may increase only modestly above its normal operating value, in which case the predetermined fault threshold will not be reached and the inverter be allowed to continue to operate.

What is needed, therefore, is a ballast with a fault detection circuit that is capable of quickly and accurately responding to an arcing condition in the lamp load. Such a ballast would represent a significant advance over the prior art.

Brief Description of the Drawings

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Figure 1 is a partial block-diagram schematic of a ballast with a fault detection circuit, in accordance with a preferred embodiment of the present invention.

Figure 2 is a detailed schematic of a ballast with a fault detection circuit, in accordance with a preferred embodiment of the present invention.

Detailed Description of the Preferred Embodiments

In a preferred embodiment of the present invention, as described in Figure 1, a ballast 10 includes an inverter 100, an output circuit 200, and a fault detection circuit 300.

Inverter 100 comprises first and second input terminals 102,104 and an inverter output terminal 106. Input terminals 102,104 receive a source of substantially direct-current (DC) voltage, V_{DC} . V_{DC} may be provided by any of a number of arrangements known to those skilled in the art; one such arrangement

consists essentially of a full-wave rectifier (coupled to a source of conventional 60 hertz alternating current) followed by a boost converter.

Output circuit 200 is coupled to inverter output terminal 106 and includes first and second output connections 202,204 for coupling to a lamp
5 load 30 comprising at least one gas discharge lamp.

Fault detection circuit 300 is coupled between output circuit 200 and inverter 100. During operation, fault detection circuit 300 monitors a first signal and a second signal within output circuit 200, and sets a fault threshold in
10 dependence on the second signal. In response to the first signal exceeding the fault threshold, fault detection circuit 300 issues a shutdown command directing inverter 100 to cease operation. Preferably, the second signal is indicative of the type of lamps (e.g., F32T8, F25T8, F17T8) in the load. Thus, fault detection circuit 300 is load-adaptable.

Preferably, during operation of fault detection circuit 300, the fault
15 threshold is set at a first level in response to the second signal being less than a first predetermined value. The fault threshold is set at a second level that is greater than the first level in response to the second signal being greater than the first predetermined level but less than a second predetermined level. The fault threshold is set at a third level that is greater than the second level in response to
20 the second signal being greater than the second predetermined level.

For example, if ballast 10 is designed to accommodate the three most common types of T8 lamps (e.g., F32T8, F25T8, and F17T8), the second signal will be less than the first predetermined level when lamp load 30 consists of one or more F17T8 lamps. The second signal will be greater than the first
25 predetermined level but less than the second predetermined level when lamp load 30 consists of one or more F25T8 lamps. The second signal will be greater than the second predetermined level when lamp load 30 consists of F32T8 lamps. Thus, the fault threshold is set in dependence on the type of lamps in lamp load 30.

30 As described in Figure 1, fault detection circuit 300 includes first and second inputs 302,304 coupled to output circuit 200, and an output 306 coupled to the inverter. The first signal in output circuit 200 is monitored via first input

302. The second signal in output circuit 200 is monitored via second input 304. In the event of a fault condition, the shutdown command is sent to inverter 100 via output 306. Fault detection circuit 300 also receives a direct current (DC) voltage supply, depicted as “+15 V” in Figure 1, that provides low voltage (i.e.,
 5 15 volts) operating power for circuit 300.

Turning now to Figure 2, in a preferred embodiment of ballast 10, inverter 100 is implemented as a half-bridge type inverter that includes upper and lower inverter transistors 110,120 and an inverter driver circuit 130. Inverter driver circuit 130 is coupled to inverter transistors 110,120 and includes
 10 a shutdown (SD) input 132 that is coupled to output 306 of fault detection circuit 300. During operation, inverter driver circuit 130 commutates inverter transistors 110,120 in a substantially complementary manner (such that, when transistor 110 is on, transistor 120 is off, and vice versa). If, however, a shutdown command (e.g., +15 volts) is received at shutdown input 132, inverter
 15 driver circuit 130 will cease commutating inverter transistors 110,120. Inverter driver circuit 130 also includes a supply input (V_{CC}) for receiving operating power from the DC voltage supply (+15 V). Inverter driver circuit 130 may be realized by any of a number of suitable circuits that are well known to those skilled in the art of electronic ballasts. For example, inverter driver circuit 130
 20 may be realized using the L6570G integrated circuit (manufactured by ST Microelectronics), along with associated peripheral components.

As described in Figure 2, inverter 100 further comprises a current sensing resistor 140 and a diode 150. Current sensing resistor 140 is coupled in series with lower inverter transistor 120. Diode 150 has an anode 152 coupled
 25 to current sensing resistor 140 and a cathode coupled to the shutdown input 132 of inverter driver circuit 130. The function of diode 150 is to isolate current sensing resistor 140 from the circuitry within fault detection circuit 300.

As is known in the prior art, current sensing resistor 140 monitors the current that flows through lower inverter transistor 120 and, in response to that
 30 current exceeding a predetermined threshold (e.g., such as what occurs under a no load fault condition wherein lamp load 30 is completely disconnected from output connections 202,204), provides a voltage at shutdown input 132 that is

sufficient (e.g., several volts or so) to cause inverter driver circuit 130 to cease inverter switching. However, as alluded to in the Background of the Invention, current sensing resistor 140 alone is not sufficient for protecting against less well-defined fault conditions, such as the arcing that occurs when a lamp is
5 being disconnected from lamp load 30 and/or output connections 202,204. Hence the need for fault detection circuit 300.

As described in Figure 2, output circuit 200 further includes a resonant inductor 210, a resonant capacitor 220, an upper half-bridge capacitor 230, an upper half-bridge resistor 232, a lower half-bridge capacitor 240, and a lower
10 half-bridge resistor 242. Resonant inductor 210 is coupled between inverter output terminal 106 and first output connection 202. Resonant capacitor 220 is coupled between first output connection 202 and the second input 304 of fault detection circuit 300. Upper half-bridge capacitor 230 and upper half-bridge resistor 232 are each coupled between the first input terminal 102 of inverter
15 100 and second output connection 204. Lower half-bridge capacitor 240 and lower half-bridge resistor 242 are each coupled between second output connection 204 and circuit ground 60.

The operation of output circuit 200 is understood by those skilled in the art, and will thus not be elaborated upon in detail herein. However, the
20 following should be appreciated:

(1) The voltage across resonant capacitor 220 will increase substantially in response to an arcing condition within lamp load 30. Thus, it is preferred that the voltage across resonant capacitor 220, or at least a voltage that is indicative thereof, is the first signal that is monitored by fault detection circuit
25 300. Correspondingly, first input 302 is coupled to first output connection 302.

(2) During normal operation of lamp load 30 (i.e., when no fault condition is present), the voltage across resonant capacitor 220 will be different for different lamp loads. For example, the normal operating voltage across resonant capacitor 220 will be highest when lamp load 30 consists of F32T8
30 lamps, and will be lowest when lamp load 30 consists of F17T8 lamps.

(3) The current that flows through resonant capacitor 220

provides an indicator of the type of lamps that are present within lamp load 30. More particularly, the current that flows through resonant capacitor 220 will increase with the power consumed by lamp load 30; for example, the current through resonant capacitor 220 will be greatest when lamp load 30 consists of F32T8 lamps, and will be least when lamp load 30 consists of F17T8 lamps. Thus, it is preferred that the current that flows through resonant capacitor 220, or at least a current that is indicative thereof, is the second signal that is monitored by fault detection circuit 300. Correspondingly, second input 304 is coupled in series with resonant capacitor 220.

Referring again to Figure 2, in a preferred embodiment of ballast 10, fault detection circuit further comprises a first diode 310, a second diode 320, a first resistor 328, a second resistor 332, a first transistor 340, a third resistor 334, a second transistor 350, a fourth resistor 348, a fifth resistor 360, a sixth resistor 364, a seventh resistor 366, an eighth resistor 368, a third transistor 370, a ninth resistor 378, a fourth transistor 380, a tenth resistor 388, and a third diode 390. First diode 310 has an anode 312 coupled to circuit ground and a cathode 314 coupled to second input 304. Second diode 320 has an anode 322 coupled to second input 304 and a cathode 324 coupled to a first node 326. First resistor 328 is coupled between first node 326 and a second node 330. Second resistor 332 is coupled between second node 330 and circuit ground 60. First transistor 340 has a gate 342, a drain 344, and a source 346; source 346 is coupled to circuit ground 60. Third resistor 334 is coupled between second node 330 and gate 342 of first transistor 340. Second transistor 350 has a gate 352, a drain 354, and a source 356; source 356 is coupled to circuit ground 60. Fourth resistor 348 is coupled between first node 326 and gate 352 of second transistor 350. Fifth resistor 360 is coupled between first input 302 and a third node 362; although depicted in Figure 2 as a single resistor, it should be appreciated that, for purposes of not exceeding component voltage ratings, it may be necessary that fifth resistor 360 be realized by multiple series-connected resistors. Sixth resistor 364 is coupled between third node 362 and drain 344 of first transistor 340. Seventh resistor 366 is coupled between drain 344 of first transistor 340 and drain 354 of second transistor 350. Third transistor 370 has a gate 372, a

drain 374, and a source 376; gate 372 is coupled to third node 362, and source 376 is coupled to circuit ground 60. Ninth resistor 378 is coupled between the DC voltage supply (+15 V) and drain 374 of third transistor 370. Fourth transistor 380 has a base 382, an emitter 384, and a collector 386; base 382 is coupled to drain 374 of third transistor, and collector 386 is coupled to the DC voltage supply (+15 V). Tenth resistor 388 is coupled between emitter 384 of fourth transistor 380 and circuit ground 60. Finally, third diode 390 has an anode 392 coupled to emitter 384 of fourth transistor 380 and a cathode 394 coupled to output 306.

The detailed operation of fault detection circuit 300 is now explained with reference to Figure 3 as follows.

Resistors 360,364,366,368 and third transistor 370 work together to provide a shutdown command when the voltage across resonant capacitor 220 exceeds its normal operating value by a certain amount. More specifically, a shutdown command will be issued when the voltage at third node 362 (which is simply a scaled-down version of the voltage across resonant capacitor 220) is high enough to turn on transistor 370.

Resistors 378,388, fourth transistor 380, and third diode 390 function as an output stage that, in response to turn on of third transistor 370, deliver the shutdown signal (e.g., 15 volts) to output 306 and the shutdown input 132 of inverter driver circuit 130.

First diode 310, second diode 320, first resistor 328, second resistor 332, third resistor 334, fourth resistor 352, first transistor 340, and second transistor 350 work together to adjust the fault threshold in dependence on the current that flows through resonant capacitor 220 (which, in turn, depends on the type of lamps present in lamp load 30). More particularly:

(1) When the power of lamp load 30 is relatively high (e.g., F32T8 lamps), the current that flows into second input 304 will similarly be relatively high, thus providing voltages that are high enough to turn on both first transistor 340 and second transistor 350. Consequently, resistors 366,368 will both be shorted out, and the voltage at third node 362 will simply be the voltage across resistor 364. Under these conditions, third transistor 370 will turn on and

issue a shutdown command only if the resonant capacitor voltage is relatively high (and, in any case, only if it is substantially higher than its normal operating value).

(2) When the power of lamp load 30 is somewhat lower (e.g., F25T8 lamps), the current that flows into second input 304 will be somewhat less than in the previous case, thus providing voltages that are sufficient to turn on second transistor 350 but not first transistor 340. Consequently, only resistor 368 will be shorted out, and the voltage at third node 362 will be the voltage across resistor 364 and resistor 366. Under these conditions, third transistor 370 will turn on and issue a shutdown command for somewhat lower values of the resonant capacitor voltage (as compared with the voltage that is required in the case of F32T8 lamps).

(3) When the power of lamp load 30 is even lower (e.g., F17T8 lamps), the current that flows into second input 304 will be even lower than in the previous case (i.e., when F25T8 lamps were present), thus providing voltages that are insufficient to turn on either first transistor 340 or second transistor 350. Consequently, neither of the resistors 366,368 will be shorted out, so the voltage at third node 362 will be the voltage across all three resistors 364,366,368. Under these conditions, third transistor 370 will turn on and issue a shutdown command for even lower values of the resonant capacitor voltage (as compared with the voltage that is required in the case of F25T8 lamps).

In this way, fault detection circuit 300 provides a fault threshold that is adjusted based on the type of lamps present in lamp load 30. Thus, fault detection circuit 300 is well suited for quickly protecting ballast 10 in the event of an emergent arcing condition in lamp load 30.

Although the present invention has been described with reference to certain preferred embodiments, numerous modifications and variations can be made by those skilled in the art without departing from the novel spirit and scope of this invention.

What is claimed is: